Metric Units and Postage Stamps

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The metric system has evolved from the French ("metre") units of 1790 to be officially recognized by the Eleventh General Conference on Weights and Measures as the International System of Units (SI) in 1960. This note brings together brief biographical notes of the scientists for whom many SI units are named, along with reproductions of postage stamps from around the world that have been issued to honor these men. This combination of science, metrics, and history may also produce the bonus of introducing someone to the hobby of topical stamp collecting.

Currently, 19 SI units are named after scientists (see Table I). Each SI symbol is unique in its spelling (usually a capital first letter of the person's name), and each unit is unique scientifically, describing a quantity to be measured using that SI unit. (Celsius alone is capitalized.)

By far the largest number of SI postage stamps feature Sir Isaac Newton. Several honor André-Marie Ampère, Allesandro Volta, and Nikola Tesla. Of the approximately 170 stamps recognizing "SI personalities," only one has been issued by the United States. France and Germany are the most frequent issuers of such stamps.

SI Base Units

The international system of units now recommended for all scientific purposes begins with seven base units. Two are named after scientists—the ampere and the kelvin.

SI Unit	Symbol	Compound Units	Quantity	Person
ampere	A	base unit	electric current	André-Marie Ampère (1775-1836)
kelvin	K	base unit	thermodynamic temperature	Lord Kelvin/William Thomson (1824-1907)
degree Celsius	°C	K *	Celsius temperature	Anders Celsius (1701-1744)
hertz	Hz	1/s	frequency	Heinrich Rudolf Hertz (1857-1894)
newton	N	kg m/s^2	force	Isaac Newton (1642-1727)
pascal	Pa	N/m^2	pressure, stress	Blaise Pascal (1623-1662)
joule	J	N m	energy, work, quantity of heat	James Prescott Joule (1818-1889); no stamp
watt	W	J/s	power, radiant flux	James Watt (1736-1819)
coulomb	C	A s	electric charge, quantity of electricity	Charles Coulomb (1736-1806)
volt	V	W/A	electric potential difference, electromotive force	Alessandro Volta (1745-1827)
farad	F	C/V	electric capacitance	Michael Faraday (1791-1867)
ohm	Ω	V/A	electric resistance	Georg Simon Ohm (1787-1854)
siemens	S	A/V	electric conductance	Werner von Siemens (1816-1892)
weber	Wb	V s	magnetic flux	Wilhelm Eduard Weber (1804-1891); no stamp
tesla	T	Wb/m^2	magnetic flux density	Nikola Tesla (1856-1943)
henry	H	Wb/A	electric inductance	Joseph Henry (1797-1878); no stamp
becquerel	Bq	1/s	activity (of a radionuclide)	Antoine-Henri Becquerel (1852-1908)
gray	Gy	J/kg	absorbed dose	Louis Harold Gray (1905-1965); no stamp
sievert	Sv	J/kg	dose equivalent	Rolf Sievert (1898-1966); no stamp

* The temperature units are the same size. The temperature in Celsius, t, = T – 273.15 K.

Table I. SI units and the persons for whom they were named.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

➤The **ampere** is the SI base unit for electric current. This unit ties the electromagnetic and mechanical units together into a coherent unit system. The ampere was defined in 1948 as the constant current which, if maintained in two straight parallel conductors of infinite length, of negligible cross section, and placed one meter apart in vacuum, would provide between the conductors a force equal to 2×10^{-7} newton per meter of length. This was an outgrowth of *Andre-Marie Ampère's* law that describes mathematically the magnetic force between two electric currents. Ampère also developed measuring techniques for electricity. A stamp from Monaco (Fig. 1) shows Ampère and what later became known as a galvanometer.

➤The **kelvin** is the SI base unit of thermodynamic temperature. The kelvin was defined in 1954 as "the fraction 1/273.16 of the thermodynamic temperature of the triple point of water," which is fixed at 273.16 K (0.01 °C). This definition makes the kelvin unit equal in size to a degree Celsius, but extending the scale down to absolute zero. In 1967 the unit name was changed from degree Kelvin to kelvin, dropping the word and symbol for degree and not capitalizing kelvin. The kelvin is named after *Baron Kelvin (William Thompson, Lord Kelvin* when knighted by Queen Victoria in 1892) who introduced the absolute scale. The one stamp that shows Kelvin (from Guinea-Bissau, Fig. 2) also shows a cable-laying ship, because Kelvin was involved in the laying of the first Atlantic cable and became a leading authority in that field.

SI Derived Units

The remainder of the SI units named after personalities are derived units, units "formed by combining base or other derived units according to algebraic relations linking the corresponding quantities." These units will be considered in order of increasing complexity, with units defined in terms of other units following those units used in their definitions.

➤The **degree Celsius** is the derived SI unit for the ordinary metric temperature scale with values from 0 to 100 degrees between the freezing and boiling temperatures of pure water under standard conditions. The relation of the degree Celsius scale to the kelvin scale is an offset by a constant factor of 273.15 K. This is the only SI unit with an additive offset, compared with the other derived SI units, which are either products or ratios of two or more SI units. (The word Celsius and the symbol C are used along with the word degree and the symbol °, unlike the word kelvin and symbol K for the absolute scale.)

The degree Celsius is named after *Anders Celsius*, inventor of the centigrade thermometer in 1742. However, his original thermometer had 100 as the freezing temperature and 0 as the boiling temperature of water. The centigrade scale was inverted in 1750, a few years after Celsius' death, and his name did not become officially attached to the SI unit until almost 200 years later, in 1948, making the term "centigrade" obsolete. The only stamp showing Celsius, issued by Sweden (Fig. 3), also shows a thermometer with the zero point at the lower end.

➤The **hertz** is the derived SI unit for frequency measurement. This unit is the reciprocal of the second, the SI base unit for time. (The symbol for hertz is a capital letter H followed by a lowercase letter z, to distinguish this unit from the henry, to be discussed later.) The hertz replaces previous usage of cycles per second and is named after *Heinrich Rudolf Hertz*. Hertz helped establish the fact that light is electromagnetic radiation. The term "Hertzian waves" was once popular for what we now call radio waves. Representative of the seven stamps known to honor Hertz is the one from San Marino (Fig. 4), issued for the centenary of radio in 1995.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

➤The **newton** is the derived SI unit for force, with force being the product of mass times acceleration. Named after *Isaac Newton*, the unit reflects Newton's research with the forces of gravity, leading to his three laws of motion and his Law of Universal Gravitation. Of the more than 80 stamps known to show or honor Newton, the one from Germany (Fig. 5) shows another of Newton's achievements, his discovery in the area of optics that white light is composed of every color in the spectrum.

➤The **pascal** is the derived SI unit for pressure or stress: force per unit area. (The symbol for pascal is a capital P followed by a lowercase a.) The unit is named after *Blaise Pascal* for his work as the founder of hydrodynamics and the discovery of the basic physical law of pressure, or Pascal's Law. He worked with atmospheric gas pressures as well as liquid pressures. A stamp from France (Fig. 6) shows Pascal and two diverse aspects of his life. The conic sections on the left reflect his work in geometry; the symbols on the right reflect the religious writings of his later life.

➤The **joule** is the derived SI unit for energy, work, or quantity of heat. Named for *James Prescott Joule,* this unit can be either force times distance or power times time. His work helped establish the mechanical equivalent of heat, that heat is a form of energy transfer, and the first law of thermodynamics, or the conservation of energy. No stamps are known to show Joule.

➤The **watt** is the derived SI unit for power or energy per unit time. Although the unit is named after *James Watt*, he actually coined the nonmetric term "horsepower" as a standard for performance of steam engines. A stamp from Wallis and Futuna Islands (Fig. 7) shows Watt and a steam engine and claims Watt as the inventor of the steam engine. Actually, Watt did not invent the steam engine, but made fundamental improvements in its design, resulting in a new type of steam engine that was patented in 1769 and widely used.

➤The **coulomb** is the derived SI unit for electric charge or quantity of electricity. In terms of SI base units, the coulomb is the amount of charge delivered by one ampere for one second. *Charles Coulomb's* Law, which describes the force between two electrical charges, is similar in form to Newton's Law of Universal Gravitation describing the force between two masses. The one stamp known to show Coulomb is from France (Fig. 8) and also pictures a Leyden jar for storing electric charge.

➤The **volt** is the derived SI unit for electric potential difference or electromotive force. One volt is the difference in potential across a conductor carrying one ampere of current when the power dissipated is one watt. *Alessandro Volta* invented the voltaic cell and voltaic pile (or battery). One of the stamps from Italy (Fig. 9) issued for the centenary of radio in 1995 shows Volta and his voltaic pile, a feature found on several Volta stamps.

➤The **farad** is the derived SI unit for electric capacitance, or the ability to hold an electric charge. A capacitance of one farad is present when one coulomb of electric charge causes a potential of one volt across the plates of a capacitor. This is a very large unit, resulting in most uses as either microfarads or picofarads for the performance of ordinary electric and electronic equipment. The unit is named for *Michael Faraday*, who discovered the principle of the electric motor, based on the dynamometer. That principle also laid the foundation for electrical generators and transformers. Of the three stamps known to show Faraday, the one from Great Britain (Fig. 10) is reproduced here.

➤The **ohm** is the derived SI unit for electric resistance. This is the only SI unit that uses a Greek letter, Ω, as a symbol. (The only other use of a Greek letter in SI terminology is for the micro μ prefix, the 10^{-6} multiplication factor.) *Georg Simon Ohm's* Law established the relationship between the volt and the ampere. The ohm is the resistance of a circuit in which a potential difference of one volt produces a current of one ampere, or alternately the resistance in which one watt of power is dissipated when one ampere flows through it. Impedance to alternating current and capacitive and inductive reactance are also measured in ohms. The only stamp known to honor Ohm (from Germany, Fig. 11) shows a resistor with colored bands for the value of resistance and Ohm's Law with the symbol U for voltage.

➤The **siemens** is the derived SI unit for electric conductance, which is the inverse of the ohm, or one ampere per volt. The unit is named after *Ernst Werner von Siemens,* inventor of the alternating-current dynamometer or motor. Germany honored its countryman on the centenary of Siemens' death with the stamp shown in Fig. 12.

➤The **weber** is the derived SI unit for magnetic flux or the dot product of magnetic field and area. The symbol for the weber combines a capital letter W followed by a lowercase letter b to distinguish the weber from the watt. *Wilhelm Eduard Weber* developed a system for measuring magnetic units. Weber is also noted for his study of terrestrial magnetism. No stamps are known to show Weber.

➤The **tesla** is the derived SI unit for magnetic flux density or webers per meter squared. *Nikola Tesla* was born in Croatia, but spent most of his life in the United States. Tesla discovered many of the principles of alternating current. A stamp issued by the United States (Fig. 13) shows Tesla and an induction motor.

➤The **henry** is the derived SI unit for electromagnetic inductance or webers per ampere. *Joseph Henry* is the only American honored by the use of his name as an SI unit. The principle of electromagnetic induction was discovered by Faraday, but named after Henry for his independent discovery of self-induction. Henry is considered one of America's great scientists and was the first Director of the Smithsonian Institution. He is also credited with inventing the first practical telegraph, which he used to gather weather information. That effort eventually led to the establishment of the U.S. Weather Bureau (later Service). No stamps are known to honor Henry.

The last three SI derived units named after personalities, all with two-letter symbols, are all related to radioactivity. These units with special names were admitted more recently into SI. They are needed in measurements related to interaction of radioactivity and living things.

➤The **becquerel** is the derived SI unit for activity of ionizing radiation. This unit is expressed in inverse seconds. *Antoine-Henri Becquerel*, who discovered radioactivity, shared the 1903 Nobel Prize in Physics with Pierre and Marie Curie, and France issued the stamp shown here (Fig. 14).

➤The **gray** and the **sievert** are the derived SI units for absorbed dose and dose equivalent, respectively. Both of these units are measured in joules per kilogram, or energy absorbed per unit mass. These units are named after *Louis Harold Gray* and *Rolf Sievert*. The difference between the units is that the first is the absorbed radiation and the second is the equivalent dose of radiation. Both units depend on the nature of biological effects caused by radiation. No stamps are known to show either Gray or Sievert.

Comment

Information given here is verified only for those stamps in my possession. Readers interested in more material on stamps honoring those for whom SI units are named (including a list of all such postage stamps and souvenir sheets known worldwide, catalog numbers, years of issue, reading lists, etc.) are invited to contact me at:
hillger@cira.colostate.edu or send correspondence to 309 North Shores Circle, Windsor, CO 80550-2614.

Acknowledgment

The author owes the genesis of his topical stamp collection to the late Louis F. Sokol, President Emeritus of the U.S. Metric Association until his death in 1996. Many additional stamps were discovered to add to Mr. Sokol's original collection, leading to this paper.

et cetera... High-Power Lasers: High-Power Density: High Pressure

"Donald Umstadter of the University of Michigan reported on an experiment in which a self-focusing laser beam passing through a plasma reached an intensity of 10^{20} watts per square centimeter, the highest yet reported for any laser. In the process of excluding plasma electrons from a narrow region forming a thin channel through the plasma, the laser creates pressures exceeding one giga-bar, higher than any other man-made pressure."[1]

1. *A.P.S. News,* July 1996

et cetera...
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